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A REVIEW OF AMPHIBIOUS ROBOTS

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Abstract

People in today's society embrace robot involvement as a smarter tool. The mid-twentieth century was a pivotal period in robotic research and development. Robots evolved from there as an industrial assistance device to the present amphibious robots. The human function is altering as a result of robotics. Robots are gradually infiltrating every industry, including manufacturing, healthcare, delivery, education, and space exploration. Scientists and researchers working in robotics place equal emphasis on ultra-large and microrobots. The notable trend in the sector is autonomous mobile robots, which automate the majority of human labor without actual human interaction. However, amphibious robots are a new developing technology in robotics that might revolutionize space functionality. This paper consists of the current classifications of amphibious robots, which primarily include the legged amphibious bot, duck feet inspired amphibious robot, salamander-like amphibious robot, sheds light on swimming and crawling in a snake-like amphibious robot which are optimized online, and it outlines a simulation-based design optimization strategy for an amphibious transformable robot carried out in different software like ANSYS FLUENT.

Keywords: Amphibious robots, ANSYS FLUENT, Biomimicry, Duck-feet, Microbots, Space functionality.

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Original Article

1. INTRODUCTION

Amphibious robots, commonly referred to as amphibots, are robots that can travel both on land and in water. They are intriguing because of their various potential applications in resource exploration, humanitarian aid, and reconnaissance. The development of robots, on the other hand, is incredibly difficult since they must have several flexible mechanisms. Unlike regular robots, amphibious robots can function in a wide range of ecological situations. They have the potential to be highly advantageous in resource exploration, cargo transfer, life rescue, and a plethora of other functions. Historically, amphibious robots employed different mechanisms for aquatic and terrestrial propulsion, such as rotors and wheels. Recent techniques have sought to reduce the footprint and intricacy of the propulsive mechanism with the intention of developing systems that replicate the performance and flexibility of living animals.

Amphibious robots tackle this obstacle in five distinct sub categories(mechanically): spherical, wheeled, legged, undulating, and soft as seen in figure 1. These classifications are based on locomotion methods and body layouts. Amphibious robots were influenced by the biometrics of fish and cetaceans' use of fins as an optimum propelling mechanism in underwater implementation. An amphibious exploring and monitoring device with a lens is developed to do a range of difficult jobs undersea, on different terrains, and in a variety of extreme weather conditions. To investigate the interactions between reconfigurable legs and transitory environments such as granular medium, a hybrid model is

now used. Robots in autonomous defense surveillance applications must travel over a multitude of platforms and surfaces. The robots can navigate rock-solid terrains and sandy beaches along the ocean's coastlines. Ultimately, amphibious robots have an overwhelming advantage in this predicament. The following are some of the advantages of amphibious robots:

• They're extremely efficient.

• Amphibious robots are simple to set up.

• The robots' fabrication mechanism is uncomplicated.

In the dynamic amphibious environment, the robots should be able to walk on uneven surfaces, navigate undersea, plus traverse through transitory zones including sandy and swampy terrain. The robots would need a high-performance propulsion system to achieve these capabilities.

Researchers across the globe attempted to design a user-friendly and sustainable design of amphibious robots and some modifications were done in existing designs.

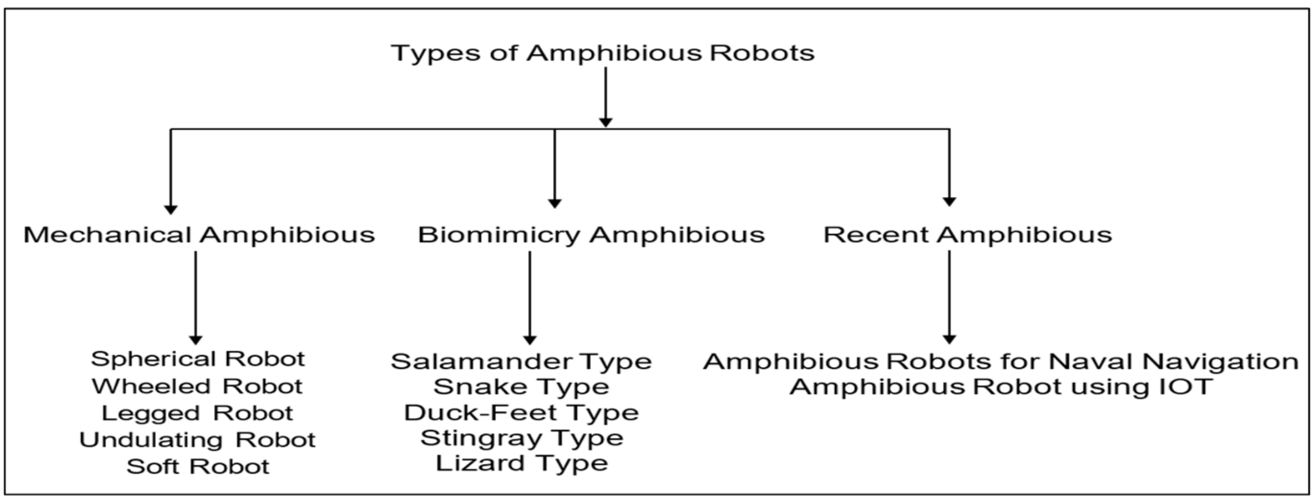

Figure 1: Classification of Amphibious Robots

Z G Zhang et al [1] presented a system design and analysis of a quadruped robot, “Rush”. It is a four-legged, kneed machine with only a single actuator per responsive leg. In the second portion of the paper, they said that a control mechanism based on sensory input is required to achieve the transition from standing to running steadily or stable running over difficult topography. When developing and constructing the Rush quadruped robot, the authors considered the following design ideas. It is critical to have a lower gear reduction ratio. Despite the fact that a high gear reduction ratio offers excellent torque enhancement, a low gear reduction ratio causes unwanted viscous friction at the joints. The tight joints will therefore require more energy to drive. Furthermore, joints having a short gear reduction ratio have a high degree of back drivability (i.e. they are not self-locking), which increases joint passive compliance which is a huge advantage. To put it another way, it is crucial for enhancing leg viscoelastic properties. Adequate viscoelastic properties can provide effective energy transformation (i.e. store and return elastic energy) as well as a positive self characteristic across the cyclic working period, lowering the mass and inertia moment of the leg, particularly the lowest linkage. It is preferable to lessen the leg's impact on the ground while also

speeding its mobility and response time, hence minimizing the interacting area at the toe's ends. This means that the touchdown region of the leg should be lowered to compensate for the limited landing surface on uneven ground. Furthermore, it might lessen the impact of the landscape. It is critical to have a tiny, economic of space, credible electronic controller. All calculations should be done online since it is preferable to build an automated and unencumbered moving robot. As a result, essential electrical components, such as the computer and sensors, must be incorporated inside the bot. In this study, the authors tackled the design of a four feet robot suited for the demands of swift-legged mobility, as well as its control to achieve stable running. A simplified controller influenced by biological ideas is presented to enable steady running over flat terrain (i.e. sprinting from a standing position to a stable bounding position) and to adapt to low-level rough terrain (i.e. sprinting up a 2cm height step). Because simpler sensory input can be examined more quickly and precisely than additional state variable measurements, the Rush four feet robot is designed to employ only single sensory feedback from the touch sensing element (e.g., running speed, jumping height). Pranavi Addanki et al [2] designed and developed an amphibious exploration robot for mining safeness and catastrophe prevention with minimal power consumption and a long mission time. The proposed design of the robot was capable of both crawling and swimming. With the help of this, they were able to sample from various hazardous sites that are out of the improving time two-wheeled limit for a normal human being. By taking the optimum values of frequency, amplitude and phase lags, they have proposed an optimized design that will consume low power and hence can be used for a longer period of time. This increased time range will substantially help in various projects where bots need longer time for a certain task.

R.Raffik et al [3] created two-wheeled amphibot. The bot is constructed with adequate balance and quite well floating effects to ensure that it floats freely. Because of the robot's movement in water, insulation and hydrophobic components have been included in its design. The motors and constructions are chosen based on the load circumstances and needs. To improve hydrodynamic motion control, supporting rods and polystyrene sheets are constructed and affixed to the bot to enhance the floating effect. Adequate sealings are used to prevent water from accessing the drive control element. The bot is designed to move in both terrestrial and aquatic ecosystems, and its velocity is monitored in both circumstances. Shiwu Zhang et al [4] developed AmphiBex-I which is a revolutionary amphibious robot with reconfigurable fin-leg composite propelling components. They demonstrated the building structure of the reconfigurable fin-leg propeller as well as its drive module. To investigate the dynamics between reconfigurable legs and intermediate environments such as granular material, a mixed(hybrid) model is adopted. The locomotion performances of feet with various elliptical forms are investigated, as evidenced by the agreement between predicted results and simulation. An analogous experiment is also carried out to investigate the locomotion performance of a two-legged robot walking with an asynchronous motion on gritty and swampy terrain. Finally, preliminary trials using AmphiHex-I walking on diverse terrains and swimming in water were carried out. These findings demonstrate that the amphibious robot's reconfigurable fin-leg systems allow it to navigate a complicated amphibious working environment.

Yu Zhang et al [5] presented an overview of the Amphibious Platform of the Driving Devices. A detailed comparison between two types of amphibious bots i.e. crawler-type amphibious vehicle and an amphibious bot with propellers was presented. Initially, inventors created a crawler-type amphibious vehicle that depended on crawler water skiing and was mostly utilized for landing. The water was moving at a slow pace. Then designers invented an amphibious bot with propellers that

were dependant on propellers having a good landing as well as high speed. They also talked about the baffle-blade drive type of Amphibious Robot which is still in the model phase. The baffle kind equipment is a drainage type drive that may be changed to a propeller-type drive if indeed the speed is increased. Alexander S. Boxerbaum et al [6] studied and designed an Amphibious robot for multiple modes of mobility. Relying on the ecologically inspired Whegs platform, a water-resistant amphibot prototype was created. After various field testing, they optimized the design and more specifically they improved the execution of Whegs and enhanced its suitability for amphibious applications. Wheel-leg blades for swimming mobility, a proactive, flexible, water-resistant, non-back drivable body component, and enhanced feet for increased mobility were among the design enhancements. These architectural breakthroughs enabled Whegs to travel tough terrain and underwater, as well as complete tasks with very less command, considerably easing the deployment of autonomous control systems. Chris Prahacs et al [7] presented about RHex, a power-autonomous-legged land-based robot, has evolved into one competent of both marine and coastal mobility. Three variants of RHex with various levels of water competence were constructed in the pursuit of an amphibious robot. While all three systems have the same basic software, electrical, and mechanical designs, different attention on elements with comparable design objectives led to the development of diverse platforms with growing amphibious navigation capability. They described a series of RHex robot designs that gradually cross the transition from ground to the ocean while also improving the platform's toughness.

Richard Harkins et al [8] prototyped an Amphibious robot for Naval navigation. A ground prototype was built and tested in the field. The initial robot architecture was built on a tracking component consisting of autonomous waypoint navigation, self-positioning, obstacle detection and avoidance, and sensor (visual) feedback transmission. The second robot design was designed keeping in mind the water-resistant technology as its prime feature. They also developed an interactive simulation that captures key elements of Whegs for evaluating robotic mobility abilities. The combination of these components established the groundwork for the creation of a novel type of highly mobility unmanned amphibious vehicle which has multi-terrain mobility, a Naval navigation system, and a water-resistant body. Alessandro Crespi et al [9] created Salamandra Robotica II, an amphibious salamander robot that can walk and swim. The robot has four feet and an actuated backbone, allowing it to both swim in the water and move on the ground. They unveiled a new robot core tech, which is an enhanced version of Salamandra Robotica I. The researchers next address a variety of questions concerning torso-feet coordination in bots and species with a sliding posture, such as salamanders, as opposed to mammals' upright posture (e.g., in lions and tigers). They especially investigate how gait features such as torso-feet, torso displacement type (offset, amplitude, and phase delay of torso swaying), and frequency impact the velocity of movement and curvature of turning motions. There are animal dataset correlations available, and the timing of torso and foot movements, as well as the relative pace of locomotion, demonstrate striking similarities with true salamander gaits. The authors found that the robot's improvements over the previous one include quicker movement and a better fit to salamander kinematics according to their experimented results. Md Norozzaman Jiko et al [10] presented a design of a smart rescue amphibious robot. They proposed a recovery bot capable of running on any uneven surface, including the stairwell. The robot can also float on liquid and dive beneath the surface. It was created using modern communication innovations, making it a more distinctive recovery bot based on the internet of things (IoT). It may be operated from any place at a given moment using a smart device owing to the use of IoT. Sensing devices were added to this robot to allow it to detect the surroundings, allowing it to be more effective in any rescue attempt by first analysing the situation and

then responding in accordance with it. As a result, this amphibious robotic device may be utilised for rescuing, surveying, and defense and study in any dangerous environment. It features a dynamic framework that allows it to be adjusted and changed in order to increase its implementation fields.

Another work on the same topic of amphibious robots has been authored by Alessandro Crespi and Auke Jan Ijspeert [11]. They addressed the difficulty of adapting locomotion behaviors to environmental factors in the control of the mobility of bots with many dof in this work. This research investigates this issue in the movement of an amphibious snake robot in order to uncover quick swimming and creeping movement patterns in a variety of situations. Their method combines Powell's method, a gradient-free optimum technique, with a mobility regulator centered on the biological idea of central pattern generators (CPGs). The fact that the jerky motions are optimized in real time, rather than as part of an offline optimization operation, is a key characteristic of this method. The authors present experiments that include swimming, crawling on flat terrain, and crawling on hills, both with the robot system and in simulations. In each of these situations, the improved jerky motions are tested to the results of systematic parameter space research. The following are the major conclusions of the experiments: 1) optimal gaits vary dramatically from one form of media to another; 2) optimums are generally peaked, i.e. when parameters are relocated from the ideal values, pace rapidly becomes insufficient; 3) this method detects ideal motions in far less steps than the methodical search; and 4) the CPG has no trouble dealing with sudden and unexpected parameter variations during the optimization technique. The implications for controlling robotic movement are discussed. Following their experiments, the authors concluded that all of the observations reported in the study indicate the necessity of finely adapting the movements to the adjacent environment. There is no particular movement that works well in all settings, and a bot that depends on a specific movement for all environments would be significantly inferior in the majority of scenarios. As a result of these practical experiments with the robot, the need for creating online optimization techniques for snake robots has been proven.

Li N et al [12] present an ideal design approach for a unique amphibious reconfigurable bot that can also execute activities in the water. They employed a multi-objective optimization strategy to design a robot with the best overall execution in the amphibious setting, in order to fulfil a number of capability requirements for the robot in water and earthly settings. The mapping linkages among the performance criteria based on the kinematics and dynamic evaluation of the robot are used to generate the multi-objective optimization problem of the device characteristics design, and then the Multi-Objective Genetic Algorithm is provided to accomplish the Pareto solution. Based on the combination weighted method of multi-attribute judgement call, the solution can be achieved and used to drive the system architecture of the reconfigurable amphibot Amoeba-II. The experiment for Amoeba-II mobility in an aquatic environment is carried out by the author and his colleagues to validate the credibility and application of the mechanism design criteria approach of an amphibious reconfigurable bot dependent on the Multi-Objective Genetic Algorithm. The testing of the robot's movement capability in fluid led to the conclusion that, in terms of propulsion performance, the lateral swing option is more stable than the vertical one for amphibious reconfigurable bots. In terms of turning performance, though, the lateral swing option trumps the vertical swing option. Based on the dynamic assessment of the robot in aquatic environments, a link between the performance indicators and the mechanism variables has been constructed. The multi-objective mechanism design issue was addressed using the Multi-Objective Genetic Algorithm, NSGA-II, and the Pareto optimum solution set was found by the authors. These were the overall conclusions drawn.

Saad Bin Abul Kashem et al [13] decided to design and build a prototype that would resemble the webbed feet of a duck and, as a result, be capable of traversing a range of terrains with acceptable efficiency and efficacy. They showcased an amphibious robot model and design based on the function of duck feet. Klann linkages were used to imitate such duck foot motion, and the control mechanism of the feet was controlled by DC motors and DC servo motors that were directed by an Arduino microcontroller. The robot detects the presence of water using conductive sensors and detects obstacles using ultrasonic sensors while walking. Because of its amphibious nature and other mobility properties, the robot can cross a range of terrains. The duck feet were first created on the SolidWorks software platform. To validate the design's validity, simulations were undertaken. The structure was stabilized by converting the robot into the quadruped by connecting four identical feet to the robot's torso. To build acceptable robot functions, several sensor and actuator combinations have indeed been developed. An Arduino Mega microcontroller was used to operate these sensing/actuating components. The prototype was developed with the balance issue of the robot in mind. The weight distribution of the robot was analyzed in detail, and batteries were placed on the upper deck of the robot's body for easy charging or switching. For every turn of the motor, the robot could advance around 7.5 cm horizontally. The speeds for no and full-load were 30 and 25 rpm, respectively. The velocity of each leg is 0.03125 m/s because it takes the motor 2.4 seconds to complete a full 360-degree rotation with a payload. In one minute, the robot was able to move around 1.9 m at a constant velocity. Finally, the developed prototype was tested on land and in water, where the robot walked and swam effectively, respectively.

Maoxun Li et al. [14] demonstrated an amphibious spherical robot with a sealed top hemispheroid, two-quarter spherical shells, and a plastic circular plate. It contains a plastic shelf to hold the micro-robots and four actuation components to move them. Each unit is made up of a water-jet propeller and two servo motors that can spin 90 degrees in both the horizontal and vertical axes. The robot has the ability to move both on land and underwater. Because the robot can walk in three different ways, the authors present trials on diverse terrains to evaluate the walking motion performance, including stability and velocity. Furthermore, several underwater tests are carried out to assess the underwater performance encompassing horizontal and vertical motions, as well as to validate the fixture and deployment mechanism for the micro-robot.

Robert Baines et al [15] presented a morphing amphibious robotic limb that combines the locomotor adaptations of sea turtles for swimming and tortoises for walking. Using a variable stiffness material connected to a pneumatic actuator system, the limb may transition between the streamlined shape of a sea turtle flipper and the load-bearing geometry of a tortoise leg. In this paper, we discuss the manufacturing and characterization of the morphing limb and demonstrate numerically how morphing between hydrodynamic and axial-load bearing modes may improve the locomotive performance of a single design on land and in water. They unveiled a new morphing limb designed for aquatic legged robots. The limb is substantially distinct from previous amphibious propulsive devices; the capacity to adjust form and stiffness allows for optimization for significantly varied locomotor patterns. When taken together, the performance of the morphing limb in the leg and flipper stages shows promise in resolving the issues posed by robotic vehicles travelling between marine and terrestrial settings.

In this publication, Mohammed Rafeeq et al [16] explored the locomotion technique for amphibious robots and how it is required not only for the study of maritime environments but also for research and industrial applications. AUVs, or

Autonomous Unmanned Vehicles, biomimetic and bio-inspired robots that are both aquatic and terrestrial in nature are referred to be amphibious. It discusses the locomotion of several reptiles and amphibians, such as the salamander and serpentines, which inspire linked mechatronics modules that move in an undulating manner. Similarly, basilisk lizards and crocodiles employ legs that are attached and lengthened to the motility body. They looked at salamanders' expansive locomotion, which included whole-body movement, a big trunk, and a tail. Amphibious robots use wheels, legs, tracks, fins, propellers, or a mix of these for maneuvering, resulting in a hybrid mechanism. Amphibious robots and their parts which help in locomotion are also mentioned, the snake inspired robots portrays a body undulation motion, the lobster uses its claws, abdomen and swimmers, a salamander with limb movements and body undulations, basilisk uses slapping and stroking of legs, frog locomotes by dual swing legs with anti-bias wheels, fish with a fin wheel propeller, while the cockroach has flexible flipper legs, the turtle favors vectored water jet thrusters with legs for locomotion. Also, the hexapod robot is an advanced-legged amphibious robot, which closely imitates the Octopus Vulgaris' locomotion. There are various classifications of amphibious robot locomotion strategies such as wheels tracked (track wheels), biomimetic, legged, biped (two-legged), quadruped (four-legged), hexapod (six-legged), octapod (eight-legged), spherical, semi-spherical (shell and legs), spherical rolling (rolling shell), hybrid, wheel leg (four-wheel leg), wheel paddle The kinematic and dynamic models of amphibious robots, the angles of the wheel plates, terrain muddy surface features, and leg shape influence, and the parameters of transformable flippers are all taken into account. The locomotion characteristic, the associated robot type, and the maximum and lowest speed on both water and land are used to compare and analyze each amphibious robot movement. The authors conducted an amphibious robot publication analysis using Scopus and IEEE explore data. Studying the databases, the mobility performance of amphibious robots in aquatic and terrestrial environments is figured out.

Dong Gyu Lee et al [17] created a Robotic Platform for amphibious mobility on both land and water. They investigated the construction of an aquatic locomotion robot based on a hexapedal mechanism. The prototype is built, and numerous experiments are carried out on it. They assessed the rolling angle and lifting force and ensured stable running on the water surface in the experiment on the water surface, while success rates for different operating frequencies were explored on the ground experiment. Two motors (motor bank-GM12FL-06) are utilized for the six 4-bar links since they have a maximum speed of 600 rpm and can provide foot force at a frequency of up to 10 Hz. A Load cell (KYOTO-651AM, sampling frequency- 40 Hz) is utilized for determining the robot's foot angle of strength in the vertical direction when exploring on water surfaces. The ground experiment was carried out on carpet and paper, with a frequency of 20 times each foot to kick the ground tests being performed without falling while the robot was moving. The experimental findings of the success ratio were measured 20 times. The authors measured such a success rate in both circumstances (ground and water). The experimental findings push the foot of water, increase the frequency and vertical force, and lower the rolling angle. The experiment from the ground increased frequency in two settings, paper and carpets were lowered success rate, the Friction coefficient is relatively modest in the environment of paper success rate is reduced from a lower frequency.

As a key issue in recent years, Raafi Dwi Susanto et al [18] suggested the single propulsion technique amphibious robot, "AM-BO." Wheels or continuous track wheels system on the land and then transitioning to propellers when on the water are two propulsive systems that may be employed, however owing to their tiny physical size, this can be difficult for small amphibious robots. Thus, the authors' goal is to create a single propulsion mechanism that can be employed on both land and

water surfaces. As a result, they opted to use paddle wheels (which offer propulsion in water) and continuous track wheels (which are commonly used in tanks for military purposes) since they will be successful in both circumstances. These wheels were chosen following a comparison with different wheels. The routing flexibility, cross country mobility, traction on slopes, speed, logistics, costing, GVW, volume, payload, maneuverability (turning radius), transportability, weight growth potential, and gap and obstacle crossing all have been taken into serious consideration. The system was designed with requirements such as light mass, functioning on both the ground and the water's surface, and the usage of a single propulsion technique in mind. The material utilized must have a low density in order for it to be buoyant. The paddle wheel was chosen over the propeller wheel because it is easier to construct and can be maneuvered on either land or water, eliminating the need for a motor. Other elements such as ground pressure (0.40875 psi is employed for simple traversal in either mud or sandy areas), torque (1.62NM to drive the robot), and motor specs (gear ratio-1:1:67, RPM-100) are determined. The AM-BO prototype is evaluated for RPM on wheels, power consumption, linear speed, voltage utilized, and how it functions on the land and water surface.

Characteristics evaluated on a novel's land Shuxiang Guo et al [19] offer an Amphibious Spherical Robot with four driving units, servo motors each, a water jet propeller, a DC motor, and a wheel. When the bot enters the water, it uses a water jet propulsion system. Many outstanding spherical robots have been constructed to date, including the world's earliest spherical robot, Rollo, designed in 1996 by Same Halme et al from Helsinki University of Technology. In 2011, the Massachusetts Institute of Technology developed a water-drive robot based on the Coanda effect. Likewise, McGill University created an amphibious robot in 2013. They agreed on the structural architecture of spherical amphibious robots, the control and energy system for which they picked Atmega2560 as the core controller and LI-PO cells for the energy system after studying prior robots developed by various researchers and institutions. The Land and Gait study is carried out on the prototype of a Novel amphibious spherical robot, which explains the quadruped and wheel movement gait in greater detail. Crawling and wheel movement on various terrains such as pavement, asphalt road, brick road, cement floor, and tile floor are also examined since terrains have varying coefficients of friction and the varied weights on the robot are 0g, 240g, and 403g, respectively. The graphs appropriately display the data. The authors determined that in each of the abovementioned movement patterns, the robot's moving speed reduces as the weight increases in the same terrain. Without weight, the maximum velocity of the robot is 8cm/s on the tile floor under a quadruped movement at a frequency of 1.25Hz, and the maximum velocity of the robot is 36.7cm/s on the tile flooring under a wheel movement pattern at a duty of 100 percent. Also, the wheel movement improves the movement speed of the amphibious spherical robot under the flat ground terrain.

Huikang Liu et al [20], released another study on Platform design for a Natatores-like Amphibious robot. Because underwater and terrestrial robots cannot satisfy the demands of a littoral amphibious environment, the research of amphibious robots is critical. The cockroach-inspired wheel-leg robot, i.e., the lobster-based robot for neutral control and cockroach-like robot with transformable leg-flipper composite propulsion mechanism called AmphiBex, the turtle-imitated robot with a repeating pattern and smooth motion, are examples of leg-type amphibious robots. The research of amphibian bionic robots based on natatores is exceedingly rare as compared to salamanders, crabs, turtles, cockroaches, and snake-like bionic items. The biometric concept in natatores is the way they move through land and water. Oscillatory wave propulsion, jet recoil propulsion, paddling propulsion, crawling propulsion, and flapping wing propulsion are the five biological underwater propulsion methods. Paddling is commonly utilized by species such as salamanders, frogs, natatores, and platypuses. The flow

area is increased by expanding the webbed toe. While on land, the biomimetic principle has two categories for natatores: going to wade, where they have small feet that are close to the front of their body, and diving, where they have a wider body but shorter legs positioned near the tail, which is convenient for diving but can cause problems with balance when on land, so to avoid falling and overcome the imbalance caused by shorter legs, they must lift their chests and crane their necks while walking. The mechanical design comprises four key aspects: the head and neck design, the leg design, the webbed feet design, and the body waterproof design, all of which have many degrees of freedom. A multi-sensor sensing system is used to develop the control technique. Raspberry Pi 3B and STM32 are used for forming a basic control system. The preliminary model provides us with a theoretical basis for building a platform while for more intuitive results like a simulation of kinematics and dynamics of the robot and to analyze the stability the authors have used ADAMS modelling. Torque at the hip, knee and ankle joint has been calculated to find out whether the current motors can satisfy the walking gait of the robot.

Chunfeng Yue et al. [21] present a work focusing on the hydrodynamic analysis of a spherical underwater robot with three movements: horizontal, vertical, and yaw. A related second-generation spherical underwater robotic (SUR-II) prototype was developed. CATIA software was used to build 3d of the flow field in order to successfully evaluate the hydrodynamic characteristics of the spherical underwater robot. When the robot executed the basic motions, the pressure contours and velocity vectors disclosed the flow field's detail. They correctly simplified the 3D models due to the intricate structure of the produced underwater robot, which caused meshing and hydrodynamic analysis restrictions. Finally, they performed the ANSYS FLUENT simulation software to examine the models for three different motions and compare the simulation outcomes to theoretical values. It revealed that the inaccuracy was less than 3%. Multiple Amphibious Spherical Robots were designed and analyzed by Xihuan Hou et al [22]. They concentrated on energy economy and ensured that underwater robots could fulfill a wide range of tasks, particularly for tiny and bionic amphibious spherical robots with limited energy. They investigated three formation configurations in terms of underwater hydrodynamic drag, with the goal of reducing the energy consumption of a multi-robot system. To calculate the drag of each individual robot and complete systems, numerical simulation based on Computational Fluid Dynamic (CFD) was used. According to simulation results, a triangle formation shape can reduce overall drag. Figure 2 depicts the drag of a triangle structure when the longitudinal distance is 0.3m. When a series and parallel formation are required, the longitudinal and transverse spacing should be as short as feasible, as shown in figure 3a.and b respectively.

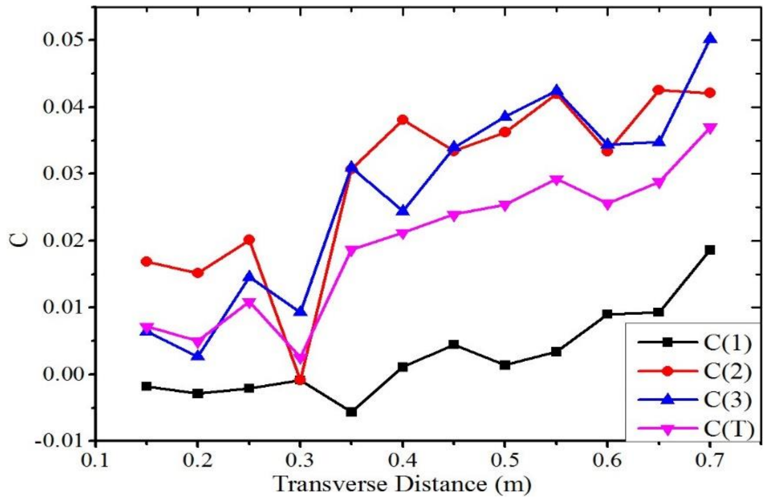

Figure 2: Triangular formation of drag at 0.3m longitudinal.

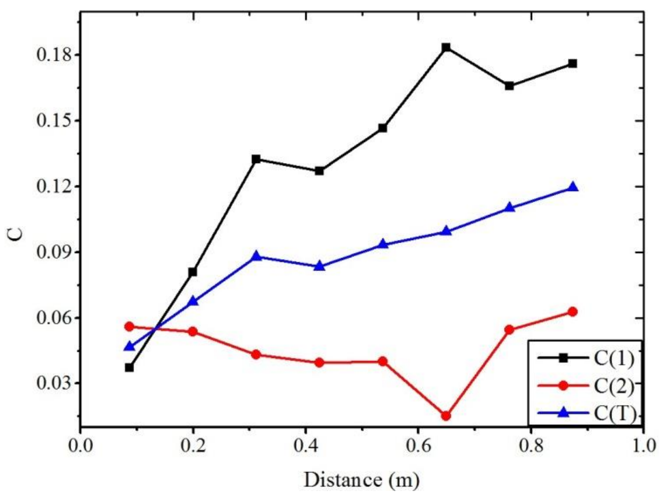

Figure 3a: Drag of Series Formation

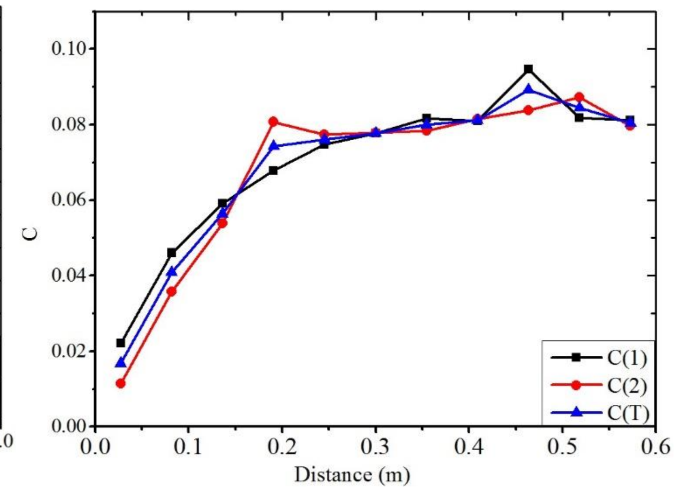

Figure 3b: Drag of Parallel Formation

Ziyue Wu et al. [23] present a revolutionary amphibious robot prototype with integrated wheel-propeller driving devices that can perform crawling locomotion on the land as well as swimming locomotion in water without modifying its driving devices. The authors propose using groups of amphibious robots as near-shore observatories or other applications that can be rapidly deployed, recovered, and redeployed in response to changing environmental conditions to meet a variety of performance requirements for the robot in aquatic and terrestrial environments. This study discusses the general design of the robot structure, and the six driving devices of the robot are operated by two separate motors, allowing the amphibious robot to easily alter locomotion modes based on the external environment. The amphibious wheel-propeller robot is made up of six wheel-propeller driving devices, two track driving devices, a mainframe structure, an energy unit, a hydraulic control unit, and other components. The wheel-propeller amphibious robot has two locomotion modes: crawling locomotion on land and swimming locomotion underwater. The hydraulic system may automatically transition between the two modes based on the external environment. Finally, the amphibious robot's hydrodynamic performances are examined using ANSYS CFD hydrodynamic calculation software. From the result, it was concluded that the aerodynamics of the robot are directly tied to

pressure on the robot, and pressure distribution is closely related to flow patterns. When the robot moves, the air flow initially comes into contact with the front of the robot; since the airflow is impeded, the speed is substantially reduced, and the dynamic pressure of the gas flow changes to static pressure, resulting in the formation of a positive pressure zone in front of the robot. According to the simulation findings, the fluid flowed smoothly over the robot body surface (with the exception of the robot's tail) and did not generate the flow separation problem. The authors observed from the pressure field that the trailing edge does not cause negative pressure, thus it was deduced that the robot's form is comparably acceptable. As a result, having a suitable design for the robot's front appearance and after body transition edge may decrease the negative pressure of these parts as much as possible, allowing fluid to flow smoothly through the robot and having outstanding aerodynamic qualities. There is a little size vortex in the robots after the body; it also produces energy expenditure, which is the major component of air resistance. As a result, while designing a robot, one should aim to decrease the vortex scale. For example, on the tail, one should try to lessen the transition of edge water chestnut and make the surface smoothly transition or use a smooth curved surface instead of water chestnut. This contributes to a reduction in vortex size and air resistance. These were some conclusions drawn from the findings.

2. SUCCESS STORIES OF AMPHIBIOUS ROBOTS

AmphiSTAR was developed by researchers at Ben-Gurion University of the Negev (BGU). Dr David Zarrouk, head of the Bioinspired and Medical Robotics Laboratory in BUG's Department of Mechanical Engineering, presented the robot at the IROS conference. AmphiSTAR, which was inspired by cockroaches and lizards, is meant to run at great speeds on the water. The robot is expected to be utilised in agricultural, search and rescue, and excavation activities, according to the researchers. AmphiSTAR is propelled by four propellers and four wheels. The axes may be shifted using the sprawl method. When the robot is on the ground, the propellers function as wheels, and when it is floating on the water, they function as fins.

Another success story in this domain is that of the Velox robot. Pliant Energy, a company based in the United States, has transformed one of its green energy technologies into a propulsion system for a swimming robot capable of exploring both land and sea. The Velox robot can traverse water, sand, stones, snow, ice, and other solid terrains. Pliant Energy originally designed the Velox fins as a device for producing power from rivers. Because swimming robots are easily movable, it proved to be a propulsive push.

3. CONCLUSIONS

Amphibians' outstanding locomotion and performance capabilities are quite fascinating to not only researchers and scientists but to us engineers too. The way the design and development of certain kinds of platforms which can imitate their locomotive strategies and control of robotic systems are impressive. This review paper ventures into the various types of amphibious robots. The organisms from whom inspiration has been taken and innumerous parts that make an amphibious robot are snakes, lobsters, salamanders, basilisk lizards, frogs, fishes, cockroaches, turtles, stingrays, Latatores (ducks). Copious amounts of research have been done on the locomotion of amphibious robots, through undulation, limb movement, swinging of legs, fin wheels, flipper legs, paddles, and so on. The authors have also done an overview of some papers where they have analyzed a spherical amphibious robot. They have done the model using CATIA software and analysis using ANSYS FLUENT.

Recent development in this domain shows that when coupled with IoT, these amphibious robots can be operated remotely and real-time data can be received directly. Naval organisations can make use of these robots for finding out the data where human exploration is difficult. Historically, the significance of robots in space exploration has been crucial owing to the uninhabitable circumstances of the solar system's non-terrestrial planets. NASA researchers hope to develop flying amphibious robots that can roll, fly, float, and swim as they explore space and planets.NASA intends to place them on Saturn's moon. Thus, amphibious robots have huge scope for further research and optimization in the imminent future.

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